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(54) FABRICATION PROCESS FOR NUCLEAR FUEL PELLETS

(71) We, AUSTRALIAN ATOMIC ENERGY COMMISSION, a Statutory Authority of the Commonwealth of Australia constituted under the Atomic Energy Act 1953-1966, of Cliffbrook, 45 Beach Street, Coogee, New South Wales 2034, Commonwealth of Australia, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an improved method for fabrication of nuclear fuel pellets. More particularly the invention relates to a cheaper method for fabricating nuclear fuel pellets of natural and inriched uranium dioxide (UO_2), plutonium dioxide (PuO_2), uranium dioxide-plutonium dioxide (UO_2-PuO_2) and similar materials.

According to the present invention there is provided a method for fabricating nuclear fuel pellets comprising the steps of mixing the nuclear fuel in powdered form with a binder; extruding the mixture of fuel and binder in the form of an elongate body of desired cross-sectional shape; parting the elongate body into pellets; pressing a pellet or a plurality of juxtaposed pellets in a press wherein the press die area is fractionally greater than the cross-sectional area of the pellet or pellets and such that the pressure of the press is greater than the pressure used for extruding; and sintering the pressed pellets.

One or more of the following advantageous features can be present in a method embodying that present invention, thereby making a cost advantage possible:—

1. There are fewer stages than in the most most commonly used methods;
2. Material passes continuously between stages, making control of nuclear criticality simpler than in methods incorporating batch type or large size equipment or stages where material is allowed to build up;
3. Dust generation is lower, an important advantage with highly toxic materials such as PuO_2;
4. Centreless grinding of sintered pellets is unnecessary, eliminating the need for strict critically control of grinding sludge and for periodical reprocessing of this sludge to recover fisssile material;
5. Recycling of rejected pressed pellets can be much simpler.

Two common conventional methods will now be described in general terms so that the advantages of the present method will become more evident. The two methods will be designated A and B.

Method A comprises feeding uranium dioxide powder to a precompaction press, a granulator, a sieve and a blender; from the blender the material passes through an automatic pelleting press, a sintering furnace, a centreless grinder and a washer-dryer, to produce finished pellets.

Method B comprises feeding uranium dioxide powder to a mixer (where it is wet-mixed with an organic pressing aid or binder) and thence to a holding tank, a spray dryer and a blender; from the blender the material passes through an automatic pelleting press, a debonding furnace, a sintering furnace, a centreless grinder and a washer-dryer, to produce finished pellets.

Methods A and B each include operations of a batch type (for example blending), operations involving the use of large size equipment (for example spray drying), or stages where material is allowed to build up (for example centreless grinding). Each such operation adds to the complexity of nuclear criticality control which is of course essential when fissile materials are being processed. The recycling of pressed pellets rejected before the sintering stage also presents difficulties in both methods. In method A these pellets must be passed through a microniser before introduction to the standard process at the precompaction

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stage. In method B these pellets are normally debonded and dissolved, and the powder is then reconstituted by precipitation and calcination-reduction.

One exemplary application of the present invention will now be described. Enriched UO_2 powder is mixed with an easily removable organic additive such as camphor, and extruded in a mixer-extruder to form an elongate body, e.g. a rod, of the material. The rod is parted automatically at the extrusion die into pellets or slugs of the required length. The pellets may then be fed into a dryer to be air dried before being pressed in an automatic pelleting press. The internal diameter of the pressing die is slightly larger than the diameter of the extruded pellet, and the pressure used in pressing is greater than that previously used for extrusion. The pressed pellets are fed to a sintering furnace and finally, if required, to a dryer emerging therefrom as finished nuclear fuel pellets with an excellent tolerance on diameter. Pellets rejected before sintering can be recycled back to the mixing stage without difficulty. An alternative example of the process to that described would be where a less easily removable organic additive is used, in which case a separate debonding stage would be necessary before sintering.

Because the extruded pellets produced by the method of the present invention are of uniform density axially and because pressing does not increase their density markedly, the hourglass taper of the sintered pellets can be very small and centreless grinding is then unnecessary. This can provide a big advantage for enriched UO_2 or UO_2-PuO_2 fuels, as reprocessing of the grinding sludge is eliminated and criticality problems due to accumulation of ^{235}U or Pu in the sludge tank are avoided. As mentioned previously the number of operations required by the present method compared to methods A and B can be reduced and dust generation can be minimized because dusty operations such as granulating, sieving, blending and spray-drying are not employed. This minimization renders the process particularly advantageous for handling enriched UO_2 or UO_2-PuO_2 fuels.

By the method of the present invention it is relatively easy to match the throughput rates of the processing stages and this avoids holding large quantities of material at any stage. Also, no large size equipment or batch type operations need be used. These are all particular advantages of the processing of fissile materials, where strict criticality control is essential at all times.

The present method may be readily adapted to produce hollow cylindrical fuel pellets, such as might be required in some reactor fuel designs. The only modifications required are in the shape of the extrusion and cold-pressing dies; otherwise the method is identical. The resultant sintered fuel pellets, of annular cross-section, can be of high tolerance on both internal and external diameters and thus require no further machining.

The method may also be adapted to produce multi-region pellets in which the fissile content varies between the regions. The resultant pellets can have high tolerance on external diameter and thus require no centreless grinding. This is a particular advantage if the outermost region in the multi-region pellet has the highest fissile content.

An embodiment of the present invention will now be described with reference to the accompanying drawings in which:—

Fig. 1 shows flow charts depicting the steps required for an embodiment of the present invention in comparison with those of methods A and B,

Fig. 2 shows in block diagram form the apparatus required for the process of the invention of Fig. 1 as well as the apparatus necessary for methods A and B,

Figs. 3 and 3b show a schematic layout of the process of the invention for single and multi-region fuel pellets, respectively, and

Figs. 4a, 4b and 4c show the forming stages for pellets of different configuration and with zones of different fissile material content.

Referring to Fig. 1 it can be seen from the flow chart layouts that the number of operations to be performed on the fuel is greatly reduced for this example in comparison with those of methods A and B.

The exemplary path shown by Fig. 1 in accordance with the present invention is particularly applicable when camphor is used as the binder such that the pellets are directly sintered in hydrogen, thereby removing the necessity of a prior debonding step.

The block diagrams of Fig. 2 show the component apparatus for this example together with those components for employing methods A and B; particularly displaying those processing stages where criticality considerations are important for enriched UO_2 or PuO_2-UO_2 fuels by the shaded areas in each diagram.

Referring now to Figs. 3a and 3b there is schematically represented a mixer 1 which feeds the mixture of fuel material and binder to the extruder and cutter 2. The resultant pellets 3 from the extruder and cutter of Fig. 3a are solid or tubular homogeneous type pellets whereas from the extruders and cutters of Fig. 3b there are produced the components for a two region pellet with the hollow sleeve pellets 4 and solid core pellets 5. The pellets are then processed through

the dryer 6 and pressed to the required dimension in the automatic press 7. From the press 7 the pellets are fired in the sintering furnace 8 to produce the final pellet which is ready for use as a source of nuclear fuel.

The forming stages of the solid, hollow and multi-zone pellets referred to above are more clearly represented in Figs. 4a, 4b and 4c, respectively, wherein Fig. 4a shows how a homogeneous solid extrusion pellet 15 progresses from its initial extruded shape to its final dimensions represented by pellet 15'. In Fig. 4a the extruded and dried pellet 15 is inserted into the pressing die 20 which is slightly larger in diameter than pellet 15, whereupon the upper die plunger 19 and the bottom die plunger 21 press the pellet in the die to give the required shape dimensions and pressed density. The pressed pellet is then sintered as schematically represented in Fig. 3 to produce the final pellet 15'.

Similarly Figs. 4b and 4c show the equivalent operations for a hollow pellet 16 and a multi-region pellet 17 and 18 wherein the solid core 18 is of lower fissile material content then the outer casing 17.

Application of the present method results in the production of natural UO_2 pellets at lower cost than by methods A or B, and with enriched UO_2 or UO_2-PuO_2 pellets the cost saving will be even greater.

This method will produce pellets of comparable density and properties to those produced by either of routes A or B.

WHAT WE CLAIM IS:—

1. A method for fabricating nuclear fuel pellets comprising the steps of mixing the nuclear fuel in powdered form with a binder; extruding the mixture of fuel and binder in the form of an elongate body of desired cross-sectional shape; parting the elongate body into pellets; pressing a pellet or a plurality of juxtaposed pellets in a press wherein the press die area is fractionally greater than the cross-sectional area of the pellet or pellets and such that the pressure of the press is greater than the pressure used for extruding; and sintering the pressed pellets.

2. The method of claim 1 wherein the pellets are dried before pressing and after sintering.

3. The method of claim 1 or 2 wherein the binder is camphor.

4. The method of claim 1 or 2 further comprising a debonding step before sintering.

5. A method according to any one of claims 1 to 4 wherein the nuclear fuel in powdered form comprises enriched UO_2 or UO_2-PuO_2.

6. A method according to any one of the preceding claims wherein the fuel pellets are solid cylindrical or tubular cylindrical or are solid cylindrical but consist of two or more regions of different fissile content.

7. A method according to claim 1 for fabricating nuclear fuel pellets substantially as described with reference to the accompanying drawings.

8. A nuclear fuel pellet when produced by a method according to any one of the preceding claims.

HASELTINE, LAKE & CO.,

Chartered Patent Agents,

28 Southampton Buildings,
Chancery Lane,
London, WC2A 1AT.

Agents for the Applicants.

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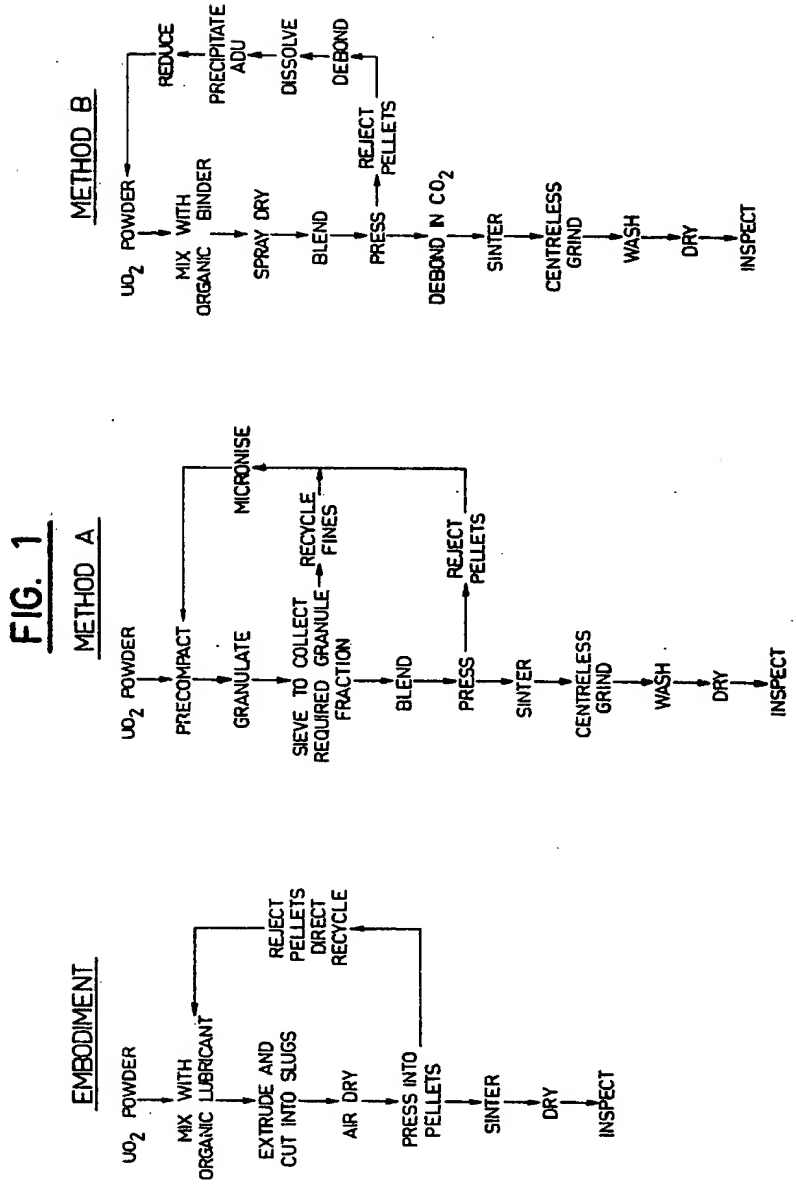


FIG. 1

FIG. 2

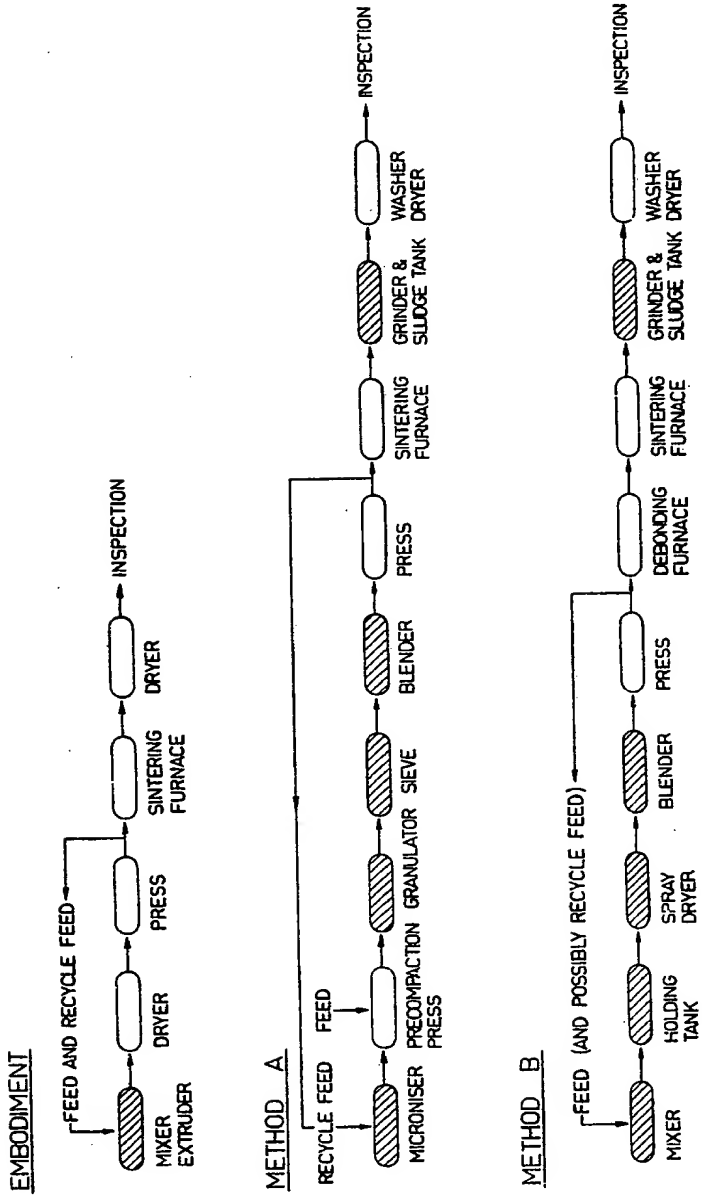
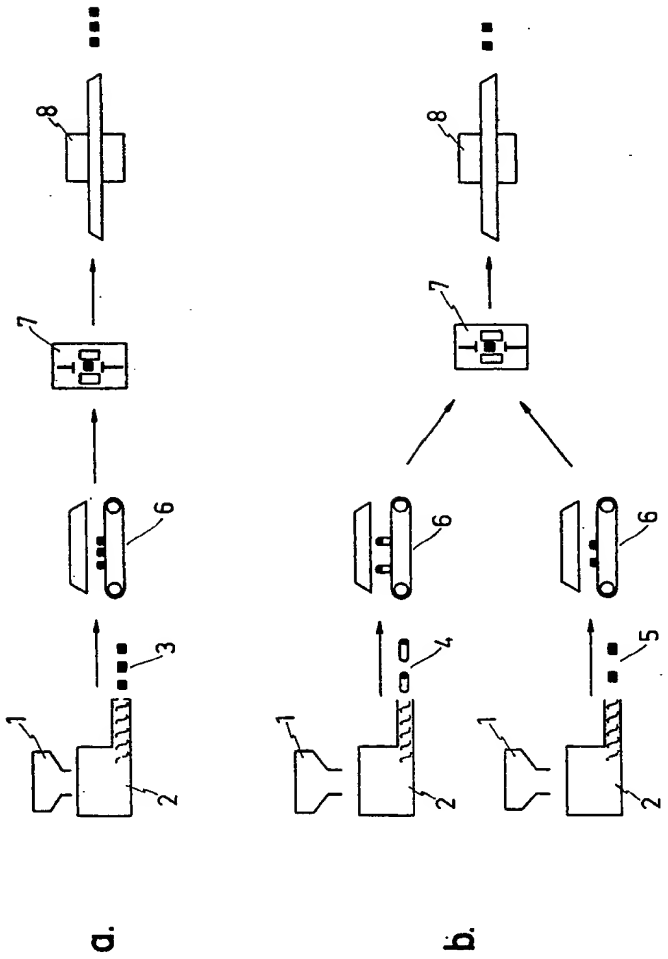


FIG. 3



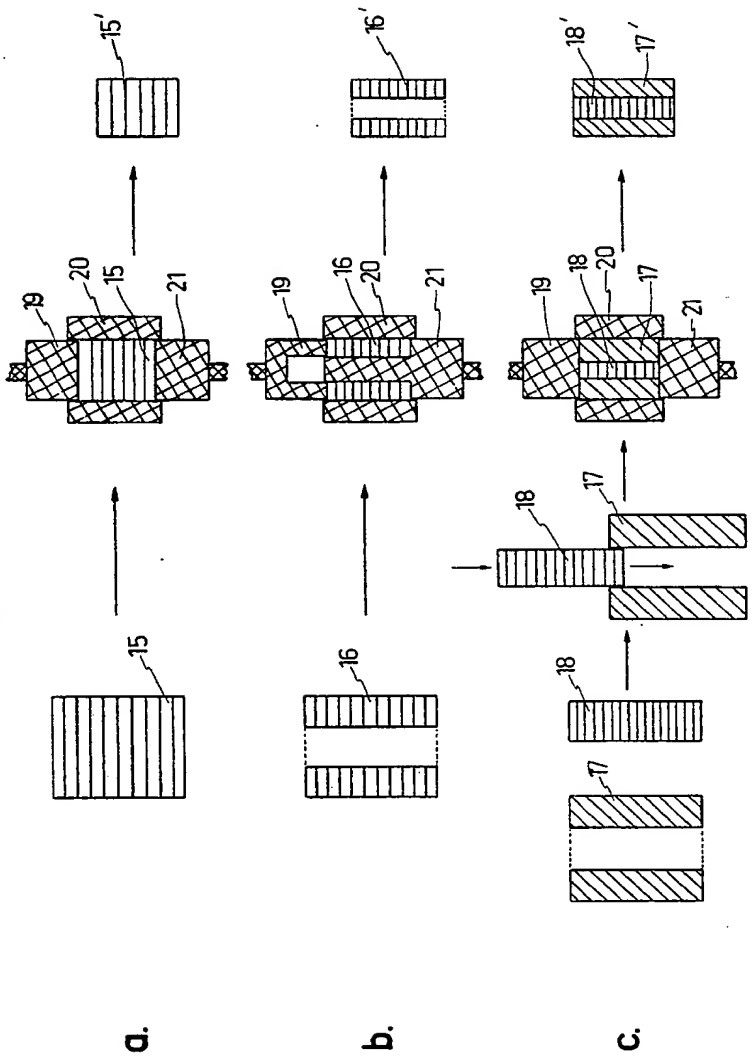


FIG. 4